J. Chem. & Cheml. Sci. Vol.3 (3), 183-200 (2013)

Variation in Coal Quality and Distribution of Ash Constituents in Different Size Fractions of a Bulk Coal Sample from Kusmunda Seam, Korba Coalfield

MANJULA SHARAFF[a], SHARAD K. VAJPAI[a] and KIRAN VAJPAI[b]

[a]Chemistry Department,
CM Dubey Postgraduate College, Bilaspur, C. G., INDIA.
[b]Chemistry Department,
Govt. Bilasa Girl's P.G. College, Bilaspur, C. G., INDIA.

(Received on: May 24, 2013)

ABSTRACT

High ash in Indian coals has necessitated incorporation of some steps to reduce ash in coals for large scale utilization as in power, sponge iron and cement industries. Possibility of reduction in the ash level without wet beneficiation has been studied on a Korba coal sample through size reduction of bulk coal and then mixing of specific size fraction(s) to obtain a composite coal with the desired ash level. The process results in composite samples of finer sizes with reduction of 5-7 units in ash. Nearly 61.1 % of total ash, 61.5 % of silica, 61.7 % of alumina, 47.3 % of ferric oxide, 48.2 % of lime, 57.61 % of alkalies as K_2O and 62.6 % of Titania are retained in the coarser size product (+25 mm) which then may or may not be subjected to gravity separation.

Keywords: Coal quality, Ash constituents, Size fractions.

INTRODUCTION

Massive coal deposits in Maharashtra, Madhya Pradesh, Chhattisgarh, Orissa, Jharkhand, Bihar and West Bengal Provinces have been sustaining large scale power generation in mega thermal power plants in the region as well as in the fuel starved states of Rajasthan, Gujarat, Delhi, Uttar Pradesh and North Eastern parts of India. On account of thick coal seams and their availability at shallow depths, these coal resources have potential for faster development and large scale exploitation to meet our fuel requirements and as such they have been accepted as good fuel sources for

the existing and up-coming power projects in the country sustaining nearly 70 percent of total power generation in India.

The incorporation of large quantities of mineral matter during coal formation and subsequent absorption from the upper and lower rock strata due to leaching action of water makes our coals dirtier due to resultant higher ash formation during their utilization in boilers and furnaces.[3] Since these coals are used generally without any beneficiation treatment to reduce their ash levels, nearly 40-50 per cent of coal utilized in the plants comes out as ash posing handling and disposal problems along with its perennial threat to environment. The ash generated in these plants has mainly silica, alumina, lime and iron oxide as major constituents representing nearly 80-87 per cent of the total ash. The remaining constituents include oxides of titanium, vanadium, manganese and magnesium.[5] In very small amounts, almost all metals of the periodic table can be found in the ash residue.[5] Some of these like copper, nickel, chromium, cobalt and zinc present in ppm levels have importance in soil fertility and plant health as micro nutrients while some others have proven toxic effects on living beings.[10] But these large quantities of ash produced with important oxides of different metals in major and minor quantities have been routinely treated as an industrial waste.

It would not be possible for us to prevent generation of large quantities of ash from power plants; attempts could be made to reduce the ash forming materials in coal. The process normally described as coal beneficiation utilises gravity separation at a stipulated effective density of separation such that the clean product would analyse desired ash. It has been perfected for metallurgical coals and now gradually being utilized in washing of non caking high ash coals for cement, sponge iron and power plants.[8]

Pit head coal beneficiation through gravity separation has been a usual practice in major coal producing countries to discard most of the ash forming material from the coal as mined, but the intimate association of dirt in our coal resources has so far been a deterrent in adopting this practice as the beneficiation does not give a complete separation of coaly matter from its mineral association and even the material to be rejected for its high ash contains sufficient calories due to organic matter left in it.[9]

Beneficiation of coal usually utilising gravity for separation of a comparatively lower ash product from a higher ash coal produce always results in to a much higher ash material which still contains sizable quanta of heat units.[3] If, however, the bulk coal coming from mine is crushed to pass a certain fixed screen size and then separated in to different size fractions, it may be possible to obtain particular size fraction(s) having desired ash while leaving the remaining material with higher ash. The process thus could be completed without a washer or alternatively, a washing unit may be coupled with the scheme to generate a further amount of cleaner coal from the residual higher ash portion. This thus would be an alternative to gravity separation for specified ash content. The distribution of ash and ash constituents in individual size fractions can be pursued using characterization and ash analysis in the laboratory for value addition of coal ash by commercial extraction of individual ash

constituents. In view of large scale production of coal ash in mega power plants, coal ash may thus prove a potential source of extraction of various ash constituents through chemical routes[5,10]

EXPERIMENTAL PARTICULARS

The distribution pattern of coal ash and their constituents in different size fractions of bulk coal has been studied in a bulk coal sample from Kusmunda seam coals in Korba coalfield. The bulk coal sample was screened on 100 mm screen and material retained on the screen was crushed applying minimum force to pass through 100 mm screen. This overall material was then screened on 25, 13, 6, 3 and 0.5 mm screens to separate 100-25 mm, 25-13 mm, 13-6 mm, 6-3 mm 3-0.5 mm and -0.5 mm fines.[1]

After recording weights of individual isolated fractions, laboratory samples were prepared from these by following BIS: 436, (Part 1/ Section 1) – 1964[2] and BIS: 436, (Part 2/ Section 2) – 1976[2] and were subjected to characterization studies BIS: 1350 (Part-1)[4] and ash analysis BIS: 1355-1984[6] in the laboratory.

Overall Samples for different combinations of these size fractions were prepared by proportionate mixing of desired size fractions on weight basis.

RESULTS AND DISCUSSION

On screening the bulk coal sample passing 100 mm screen on 25, 13, 6, 3 and 0.5 mm screens the bulk sample was separated in to 100-25 mm, 25-13 mm, 13-6 mm 6-3 mm, 3-0.5 mm fractions and –0.5 mm fines. These fractions were weighed and laboratory samples prepared from these individual and constituted samples were subjected for determination of moisture, ash (Proximate analysis)[4] and ash constituents[6]. The results of the exercise have been summarized in Table - 1 and Table - 2 and diagrammatically represented in Fig. 1

Distribution of coal ash in different size fractions:

The bulk coal sample from Kusmunda area analyses 36.3 per cent ash on dry basis. Different size fractions isolated from the bulk coal vary widely in their quality and contribution by weight in the overall bulk sample. The 100-25 mm size fraction forms 54.9 per cent of the bulk coal sample analysing 40.4 per cent ash on dry coal basis. This is nearly 4 units higher than the bulk sample and represents 22.18 parts by mass of the size consist and 61.1 per cent of the total ash in the bulk coal sample. The 25-13 mm fraction forms 8.8 per cent by mass of the bulk coal and analyses 35.3 per cent ash_{dry}. This would be 3.1 parts by mass of the size fraction and 8.54 per cent of the total ash in the bulk sample. The 13-6 mm size material represents 13.1 per cent of the coal sample analyzing 26.5 per cent ash_{dry} and retains 11.68 per cent of the total ash. The 6-3 and 3-0.5 mm coals represent 6.2 and 10.1 per cent of the total coal sample and analyze nearly 14 units lower ash as compared to the 100-25 mm fraction and 10 units lower than the bulk coal as well as the –0.5 mm fines. The ash retained in these fractions forms 4.52, 7.33 and 6.83 per cent of the bulk coal ash.[1]

Ash composition of different size fractions:

In bulk coal Silica 63.81 per cent and Alumina 30.01 per cent contribute

nearly 94 per cent of ash while Fe_2O_3, CaO, MgO, Alkalies (K_2O and Na_2O)), P_2O_5, SO_3 and oxides of some trace elements contribute the remaining 6 per cent. In different size factions Silica and Alumina have been found to be varying between 62.57 and 64.2 per cent and 27.44 and 30.32 per cent respectively. Both these constituents show decreasing trend as we move to the lower size fractions except for the –0.5 mm size where silica rises to 63.33 per cent. A wider variation is found for ferric oxide analysing between 1.55 and 4.03 per cent of ash for individual size fractions. A continuous increase in concentration with lower sizes is a striking feature. Lime and Magnesia vary gradually following similar trend and analyse between 0.60 and 1.20 per cent for CaO and 0.68 and 0.77 per cent for MgO. Alkalis have small contribution with sodium oxide analysing between 0.08 and 0.10 per cent while potassium oxide contributing 1.01 and 1.62 per cent. P_2O_5 shows variations between 0.01 to 0.05 per cent with its distribution amongst different size fractions not following any particular trend.

Thus the distribution of different ash constituents in different size fractions can be summarized as below:

Silica and Alumina contents in ash represent major proportion of coal ash while Fe_2O_3, K_2O, TiO_2, CaO, MgO, Na_2O, P_2O_5 and SO_3 constitute a small proportion of coal ash. The per cent silica and alumina is found generally decreasing from higher size fractions to lower size fractions while Fe_2O_3, CaO, K_2O, and SO_3 increase and TiO_2, MgO, Na_2O and P_2O_5 concentrations remain practically unchanged.

The distribution of different ash constituents has been given in Table-2 and Fig. 1

Distribution of Silica in different size fractions

The silica present in coal ash of individual size fractions as also the bulk coal varies in a narrow range of 62.57 and 64.20 per cent of ash. This in terms of dry coal would amount to a variation between 16.46 and 25.93 per cent in different size fractions. When represented as fraction of total silica in 100 tonnes of bulk coal sample, the 100-25 mm size fraction is found to retain 14.24 tonnes of silica representing 61.50 per cent of total silica in bulk coal sample. The remaining size fractions retain 4.40 to 11.60 per cent of total silica.

The results have been diagrammatically represented in Table-3 and Fig. 2.

Distribution of alumina in different size fractions

The alumina present in coal ash of individual size fractions as also the bulk coal varies between a range of 27.30 and 30.32 per cent of ash. This in terms of dry coal would amount to a variation between 9.86 and 12.25 per cent in different size fractions. When represented as fraction of total Alumina in 100 tonnes of bulk coal sample, the 100-25 mm size fraction is found to retain 6.72 tonnes of alumina representing 61.70 per cent of total alumina in bulk coal sample. The remaining size fractions retain 4.50 to 11.80 per cent of total alumina.

The results have been represented in Table-4 and diagrammatically in Fig. 3.

Distribution of Fe_2O_3 in different size fractions

The ferric oxide concentration in coal ash of individual size fractions

including bulk coal is found to vary between a range of 1.55 and 4.04 per cent of ash. In terms of dry coal this would amount to a variation between 0.63 and 1.45 per cent in different size fractions.

When represented as fraction of total ferric oxide in 100 tonnes of bulk coal sample, 0.34 tonne representing 47.3 per cent of total ferric oxide has been retained in 100-25 mm size fraction. The remaining size fractions retain 5.80 to 13.10 per cent of total ferric oxides.

The distribution of iron oxides has been presented in Table-5 depicted in the pie diagram in Fig.4.

Distribution of CaO in different size fractions

The result for the individual size fractions shows an increasing trend in lime content in their ash. The bulk sample ash analyses 0.74 per cent CaO and show a narrow ranged (from 0.80 to 1.20 per cent of ash) increasing trend as we move to lower size from higher sizes. CaO varies between 0.22 to 0.44 per cent of dry coal.

When represented as fraction of total CaO in 100 tonnes of bulk coal sample, the higher size fraction 100-25 mm contains 0.13 tonne or 48.2 per cent of total 0.27 tonnes of CaO in bulk coal while lower sizes analyze CaO varying between 6.3 and 12.6 per cent. The distribution of CaO has been presented in Table - 6 depicted in the pie diagram in Fig.5

Distribution of K_2O in different size fractions

Normally Alkalies (in terms of Na_2O and K_2O) constitute up to 1-2 per cent of coal ash. The total K_2O in terms of bulk coal sample is a mere 0.40 per cent.

The K_2O present in coal ash of individual size fractions as also the bulk coal varies in a narrow range of 1.01 and 1.12 per cent except for the –0.5 mm size where it has been analysed as 1.62 per cent. This in terms of dry coal would amount to a variation between 0.41 and 0.59 per cent in different size fractions.

When represented as fraction of total potassium oxides in 100 tonnes of bulk coal sample, the 100-25 mm size fraction is found to retain 0.23 tonnes representing 57.60 per cent of total potassium oxides in bulk coal sample. The remaining size fractions retain 4.50 to 12.30 per cent of total potassium oxide.

Table 7 and the pie diagram in Fig. 6 represent contribution of different size fractions in total potassium oxide present in bulk coal.

Distribution of TiO_2 in different size fractions

The bulk sample ash analyses 1.11 per cent TiO_2 and about constant value (from 0.97 to 1.14 per cent of ash) has been found as we move to lower size from higher sizes. TiO_2 varies between 0.27 to 0.45 per cent of dry coal.

When represented as fraction of total Titania in 100 tonnes of bulk coal sample, the higher size fraction 100-25 mm contains 0.25 tonne or 62.60 per cent titania of total 0.40 tonnes in bulk coal while lower sizes analyze titania varying between 5.0 and 11.8 per cent. The distribution of titania has been presented in table - 8 depicted in the pie diagram in Fig.7.

Composite Coal samples

Separation of the bulk coal sample in to different size fractions offers possibilities for remixing of selected fractions to constitute a composite sample based on stipulated ash in dispatch coal for the industries. The remaining material forms the second composite sample and the economics of the process will be dictated in terms of quality and quantity of this second material. Accordingly various possibilities of selection of size fractions for a composite coal have been summarized in Table – 9 along with variation in their ash constituents. The bulk sample screened on 25 mm screen gives a + 25 mm size material representing 54.9 per cent yield of the bulk sample with 40.4 per cent dry ash (nearly 4.1 per cent higher than the original sample) leaving behind 45.1 per cent yield of the bulk sample analyzing 5 units lower in ash. Generally non caking coals are washed with an objective to get cleaner coals with around 32 per cent dry ash. Thus here we have a case where a mere separation of bulk sample in to + 25 and – 25 mm fractions, in which the – 25 mm has nearly same ash as stipulated cleaned coal. The lower yield of cleaner material is well compensated in terms of much higher calories still present in the higher ash fraction. The variation in terms of ash constituents is likely to affect fusibility of ash, colour of products etc. when ash gets mixed in the product. There is also a segregation of different ash constituents in the plus material as it retains 61.1 per cent ash of total ash, 61.5 per cent of total SiO_2, 61.7 per cent of total alumina, 47.3 per cent of total Fe_2O_3, 57.6 per cent of total K_2O, 48.2 per cent of total lime and 62.6 per cent of total Titania in bulk coal sample.

If the bulk sample is passed through 13 mm screen the + 13 mm material representing 63.7 per cent yield of bulk sample with 39.7 per cent dry ash, 3.4 units higher than the bulk coal while the minus 13 mm material would have nearly 6 units lower ash.

Similarly screening the bulk coal on 6 mm screen the + 6 mm material would represent 76.8 per cent yield of the bulk sample with nearly 2 units higher ash content than the original sample while the remaining –6 mm material would analyze 29.2 per cent ash showing an improvement of over 7 units. The two fractions differ in their ash content by more than 9 units. Screening the bulk sample on 3 mm screen would result in separation of the coarser coals to 83 per cent yield with 37.5 per cent ash while the cleaner fines amounting to 17 per cent yield of total coal would analyze 30.2 dry ash. Exclusion of below 0.5 mm fines from the bulk coal has not indicated any improvement in quality of products.

Variation of ash constituents in selected composite samples

The variations of different ash constituents has been studied for the above constituted samples and given in Table-10 to 15.

It is seen that the higher size composites have comparatively higher SiO_2 per cent in dry ash than the corresponding lower size composites by around 1 unit. A slight decrease in silica content has been found with more and more incorporation of lower sizes in the composite sample. The total fraction of silica retained in the

composite samples on bulk coal basis is 14.24 and 9.36 in +25 and –25 mm composites, 16.21 and 6.95 in +13 and – 13 mm composites, 18.90 and 4.26 in +6 and –6 mm composites 19.93 and 3.23 in +3 and –3 mm composites and 21.59 and 1.57 tonnes of silica of bulk coal in +0.5 and –0.5 mm composite samples.

Alumina per cent in different possible composite samples show nearly the same trend as silica with larger size composites having higher proportions than the finer size composites. The lower sizes have decreased alumina content in their ash varying from 29.61 to 27.45 per cent as we go down to finer composites. The alumina content in all the plus size composites nearly remains constant at around 30.3 per cent level.

The total fraction of alumina, on dry bulk coal basis, retained in the composite samples is 6.72 and 4.17 in +25 and –25 mm composites, 7.66 and 3.23 in +13 and –3 mm composites, 8.94 and 1.95 in +6 and –6 mm composites 9.43 and 1.46 in +3 and –3 mm composites and 10.21 and 0.68 tonnes in +0.5 and –0.5 mm composite samples respectively.

The Fe_2O_3 per cent in ash of different composite samples is found to increases in finer size composites and the increase varies between 1.21 and 2.3 units as we go on eliminating more and more upper sizes. All the plus sizes also show a slight but definite increase in their Fe_2O_3 content in ash from 1.55 per cent to 1.83 per cent as we include finer material in the composition. This suggests friability of iron containing minerals which therefore get more concentrated in the finer sizes. The total fraction of Fe_2O_3 retained in the composite samples on bulk coal basis is 0.34 and 0.38 tonnes in +25 and –25 mm composites, 0.40 and 0.32 tonnes in +13 and –13 mm composites, 0.49 and 0.23 tonnes in +6 and –6 mm composites 0.53 and 0.19 tonnes in +3 and –3 mm composites and 0.62 and 0.10 tonnes in +0.5 and –0.5 mm composite samples.

The CaO content is found to increase in finer size composite samples but its percentages are higher in minus sizes by 0.4 -0.5 units than the corresponding coarser size composite samples suggesting concentration of calcium minerals in finer sizes.

The fraction of CaO retained in the composite samples on bulk coal basis is 0.13 and 0.14 tonnes in +25 and –25 mm composites, 0.16 and 0.11 tonnes in +13 and –13 mm composites, 0.19 and 0.08 tonnes in +6 and –6 mm composites 0.21and 0.06 tonnes in +3 and –3 mm composites and 0.24 and 0.03 tonnes in +0.5 and –0.5 mm composite samples.

A slight increase of K_2O per cent in coarser size composite samples has been found as we incorporate more and more fine sizes in the sample while there is a rapid increase in finer size fractions the percentages of K_2O is found increasing from 1.20 to 1.61 per cent. It means that K_2O has been segregated in finer sizes.

The total fraction of K_2O retained in the composite samples on bulk coal basis is 0.23 and 0.17 tonnes in +25 and –25 mm composites, 0.26 and 0.14 tonnes in +13 and –13 mm composites, 0.31 and 0.09 tonnes in +6 and –6 mm composites 0.33 and 0.07 tonnes in +3 and –3 mm composites and 0.36 and 0.04 tonnes in +0.5 and –0.5 mm composite samples.

Variation in Ash Constituents in composite samples: MgO, Na_2O, SO_3 & P_2O_5

These oxides are found in very low proportions in our coals. Their variation in different size consists of composite samples has been summarized in the Table- 15 below:

The coal ash from different composite samples have analysed nearly constant MgO content for coarser size samples which are slightly lower than those found for the minus composite samples.

The Na_2O content in various composite samples plus as well as minus shows a near constant value of 0.08-0.1 per cent.

The sulphatic sulphur content represented as sulphuric anhydride SO_3 per cent in ash is found to be nearly constant at 0.04-0.06 per cent in all the plus composite samples while the minus samples show a slight variation of 0.03-0.06 units in the minus composites which contain 3 to 5 times higher concentration than their corresponding plus composites.

The bulk coal sample has only a small concentration of phosphatic minerals and as such the coal ash for the bulk as well as different size fractions and composite samples analyse 0.02-0.03 per cent P_2O_5.

It has been seen that the minus 0.5 mm material representing 6.9 tonnes of the bulk sample analyses 35.9 per cent ash on dry coal basis. If this fraction is mixed with higher ash composites in the proposals as discussed above, the new composites are found to show improvement in quality of the products as summarized in the table -16.

On mixing –0.5 mm fines with comparatively higher ash with the plus composites considered above , the quality of new composite product is hardly affected ash decreases by 0.1-0.3 per cent but their counterparts, the new finer (minus) composites show an improvement in quality as their ash decreases by 0.7 to 3 units. Thus +25mm and –0.5mm composite, representing 61.8 tonnes yield with 39.9 per cent ash can be separated from the remaining bulk which now analyses only 30.4 per cent ash on dry basis. Thus it could be possible to use this 38.2 tonnes product as cleans without having subjected to any coal beneficiation process. The minus 13 and 6 mm composites (excluding 0.5 mm material) show much improvement in quality of coal with ash 29.0 and 26.2 per cent respectively and can be directly used by industries using finer coals without any beneficiation exercise. The corresponding plus size composites have nearly the same ash as they had when 0.5 mm material was not mixed with them. Further silica has been found to be 64.32 per cent in +25mm (incl. (–0.5) mm), while in -25mm (excl. (–0.5) mm) size it has been 63.29 per cent, about 1 per cent less than from the plus composite. There is slight increase in Fe_2O_3, CaO, K_2O, and MgO in lower size, but this nominal increase is not likely to affect the behaviour of these composites at higher temperatures.

It is discernible that the smaller size and cleaner minus composite samples retain lesser proportions of ash as well as different ash constituents except for Fe_2O_3 and CaO which show a greater tendency of concentrating in finer sizes.

SUMMARY AND CONCLUSION

In an attempt to establish an alternative route to reduce ash content of

non caking coals without subjecting them to gravity separation, a bulk coal sample from Kusmunda seam has been studied in details for quality and properties in terms of ash constituents of different size fractions and possible reconstituted samples.

The bulk sample was screened on 100 mm screen and all the plus 100 mm material was hand crushed to pass the screen. The mixed minus 100 mm material now was screened on 25, 13, 6, 3 and 0.5 mm screens to separate 100-25, 25-13, 13-6, 6-3, 3-0.5 and through 0.5 mm size fractions. These fractions were weighed and processed for preparation of laboratory samples for determination of ash, moisture and ash composition. The results of the studies have been reported on dry bulk coal basis to avoid variations due to different moisture contents of the samples.

It is seen that fractionation in to different size consists has resulted in to differentiation in quantity and constitution of ash. The results of ash determination on dry coal basis show a variation of as much as 14 units of ash in isolated fractions.

The 100-25 mm fraction has analyzed 40.4 units of ash as compared to 36.3 units in original bulk sample. Except –0.5 mm material which retains the ash level as of original coal, the lower fractions have analyzed lower ash values as more and higher size material gets removed. The 3-0.5 and 6-3 mm fractions have nearly 10 units lower ash than the original sample.

The 100-25 mm fraction represents 54.9 per cent mass of the original sample and retains 22.2 parts (61.1 per cent) of total ash of the bulk sample. The lower size fractions vary in their weights and have 1.63 to 4.24 units of total ash (36.3 units of dry bulk coal).

The total silica for the bulk sample has been found to be 23.16 per cent by mass of which the 100-25 mm fraction retains 14.24 parts (61.5 per cent) while lower fractions have retained silica between 1.03 and 2.69 parts. Again of the total 10.89 parts of alumina found in the bulk dry coal, the 100-25 mm fraction retains 6.72 parts (61.7 per cent) while the lower size fractions are found to retain between 0.49 to 1.28 parts of total alumina. The Fe_2O_3 content has been 0.34 parts (of total 0.72 per cent by mass of bulk coal) in 100-25 mm fraction, while the lower fractions have retained 0.04-0.10 parts of the total Fe_2O_3 for the bulk coal. Distribution of CaO has been nearly uniform varying between 0.02 and 0.03 in different size fractions. Alkalis in terms of K_2O has been found to vary between 0.02 and 0.05 parts in lower sizes while the 100-25 mm size fraction has retained 0.23 parts of total K_2O (0.40 parts of bulk coal by mass).

Constituted samples prepared by mixing of different size fractions in the proportions of their original weights as obtained on screen analysis have been studied for their ash, moisture and ash composition. The minus 25 mm fractions has analyzed 31.3 per cent ash which is 9.1 units lower than the plus counterpart and 5 units lower than the original bulk sample.
A similar difference of 9.4 and 9.2 units have been found in minus 13 and minus 6 mm material over their counter parts while a difference of 7.3 units has been found for minus 3 mm material. The ash of minus composite samples has been found to be 5-7 units lower than the bulk sample and is nearly in the range of 29-31 per cent level. The yield of the bulk coal sample is found to

vary between 17 and 45.1 per cent and will be deciding factor for their selection as the cleaner product.

The plus 25, plus 13, plus 6, plus 3 and plus 0.5 mm composite samples form 54.9, 63.7, 76.8, 83.0 and 93.1 per cent of the total mass of the bulk coal respectively. The silica retained in these samples has been found to be 14.24, 16.21, 18.90, 19.93 and 21.59 units of total silica (23.16units). These constituted samples have retained 6.72, 7.66, 8.94, 9.43 and 10.21 units of total alumina,0.34, 0.40, 0.49, 0.53 and 0.62 units of Fe_2O_3 , 0.13, 0.16, 0.19, 0.21 and 0.24 units of CaO and 0.23, 0.26, 0.31, 0.33 and 0.36 units of K_2O respectively.

Mixing the minus 0.5 mm material with larger plus constituted samples further reduces the ash burden in the minus reconstituted material and makes them more acceptable product without affecting the quality of the plus reconstituted samples. The minus 25 mm, minus 13 and minus 6 mm material (without 0.5 mm fines in them) thus constitute 38.2, 23.4 and 16.3 per cent mass of the bulk coal and analyze ash as 30.4, 29.0 and 26.2 per cent. This is a reduction of 6-10 units of ash from the bulk sample and 9.5-12.0 units from their counterparts (with 0.5 mm fines).

Size separation is a normal practice in gravity separation practices and if cleaner fraction(s) are separated out from the bulk coal, the remaining dirtier coal can be subjected to gravity separation to increase the total quantum of cleaner coal output for user industries. The variation in quantity of different ash constituents may form the nucleus for planned extraction of ash constituents from ash generated on use of these coals providing a value addition to our coal resources.

Table 1: Distribution of coal ash in different size fractions Kusmunda seam coal, Korba CF

Size fraction	Weight (in tonnes)	Dry Ash %	Ash as % of mass of size consist	Ash as part of total ash in bulk coal
100-25 mm	54.9	40.4	22.18	61.10 %
25-13 mm	8.8	35.3	3.10	8.54 %
13- 6 mm	13.1	32.4	4.24	11.68 %
6- 3 mm	6.2	26.4	1.64	4.52 %
3-0.5mm	10.1	26.3	2.66	7.33 %
–0.5mm	6.9	35.9	2.48	6.83 %
Bulk coal	100.0	36.3	36.30	100 %

Dry ash is ash on dry coal basis

Table 2: Ash Composition of different size fractions, Kusmunda seam coal, Korba CF

Size Fraction (mm)	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	K_2O %	Na_2O %	SO_3 %	P_2O_5 %	TiO_2 %
100-25	64.20	30.32	1.55	0.60	0.69	1.01	0.11	0.04	0.04	1.14
25-13	63.54	30.26	2.01	0.86	0.70	1.08	0.08	0.06	0.01	1.11
13-6	63.47	30.18	2.19	0.80	0.70	1.09	0.08	0.06	0.04	1.09
6-3	62.80	30.16	2.53	1.01	0.73	1.10	0.09	0.12	0.05	1.12
3-0.5	62.57	29.49	3.32	1.05	0.76	1.12	0.09	0.27	0.01	1.03
–0.5	63.33	27.44	4.03	1.20	0.77	1.62	0.10	0.22	0.02	0.97
Bulk sample	63.81	30.01	1.99	0.75	0.70	1.09	0.09	0.09	0.04	1.11

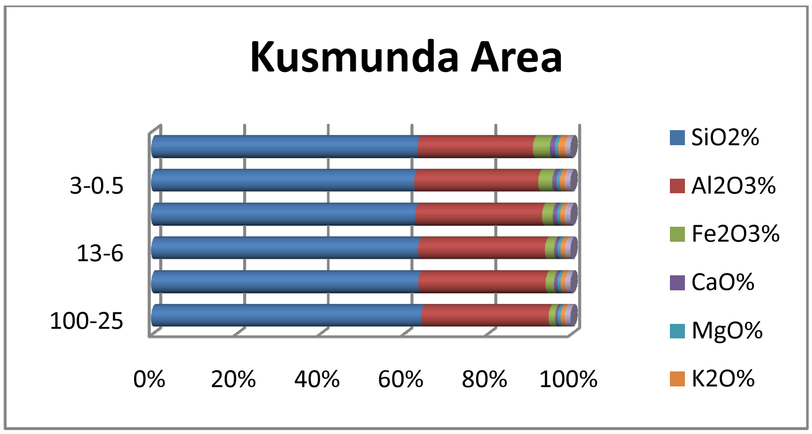

Fig. 1: Distribution of ash constituents in different size fractions.

Table 3: Distribution of Silica in different size fractions Kusmunda seam coal, Korba CF

Size Fraction (in mm)	SiO_2 as % of dry ash	SiO_2 as % of dry coal	Fraction of SiO_2 in bulk coal (in tonnes)	Fraction % of total SiO_2 in bulk coal
100 – 25	64.20	25.93	14.24	61.50
25– 13	63.54	22.43	1.97	8.50
13 – 6	63.47	20.56	2.69	11.60
6 - 3	62.80	16.57	1.03	4.40
3 - 0.5	62.57	16.46	1.66	7.20
– 0.5	63.33	22.72	1.57	6.80
Bulk Sample	63.81	23.16	23.16	100

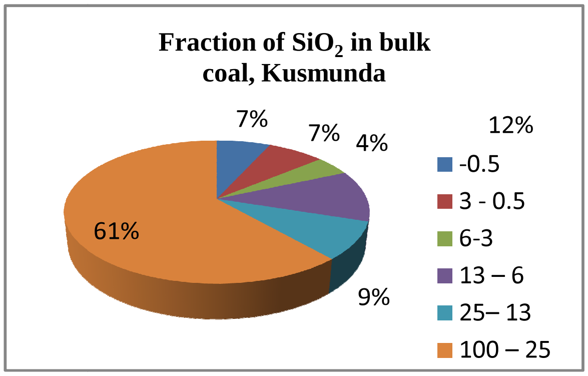

Fig. 2: Distribution of Silica in different size fractions

Table 4: Distribution of Alumina in different size fractions Kusmunda seam coal, Korba CF

Size Fraction (in mm)	Al_2O_3% as % of dry ash	Al_2O_3 as % of dry coal	Fraction of Al_2O_3 in bulk coal (in tonnes)	Fractional % of total Al_2O_3 in bulk coal
100 – 25	30.32	12.25	6.72	61.70
25 – 13	30.26	10.68	0.94	8.60
13 – 6	30.18	9.78	1.28	11.80
6 - 3	30.16	7.96	0.49	4.50
3 - 0.5	29.49	7.76	0.78	7.20
– 0.5	27.30	9.86	0.68	6.20
Bulk Sample	30.09	10.89	10.89	100

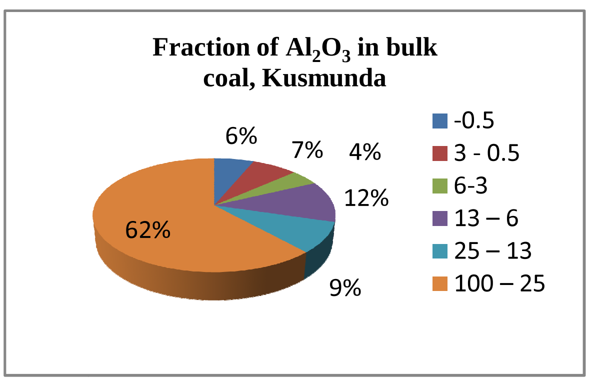

Fig.3: Distribution of Alumina in different size fractions

Table 5: Distribution of Fe_2O_3 in different size fractions Kusmunda seam coal, Korba CF

Size Fraction (in mm)	Fe_2O_3% as % of dry ash	Fe_2O_3 as % of dry coal	Fraction of Fe_2O_3 in bulk coal (in tonnes)	Fractional % of total Fe_2O_3 in bulk coal
100 – 25	1.55	0.63	0.34	47.30
25 – 13	2.01	0.71	0.06	8.70
13 – 6	2.19	0.71	0.09	12.90
6 - 3	2.53	0.67	0.04	5.80
3 - 0.5	3.32	0.87	0.09	12.20
– 0.5	4.04	1.45	0.10	13.10
Bulk Sample	1.99	0.72	0.72	100

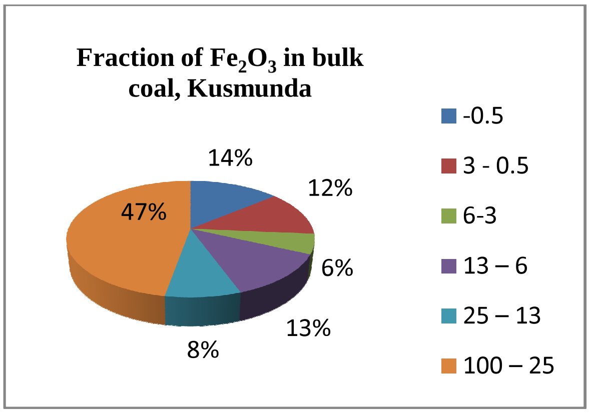

Fig.4: Distribution of Fe2O3 in different size fractions

Table 6: Distribution of CaO in different size fractions Kusmunda seam coal, Korba CF

Size Fraction (in mm)	CaO% as % of dry ash	CaO as % of dry coal	Fraction of CaO in bulk coal (in tonnes)	Fractional % of total CaO in bulk coal
100 – 25	0.60	0.22	0.13	48.2
25 – 13	0.86	0.30	0.03	11.3
13 – 6	0.80	0.26	0.03	12.6
6 - 3	1.01	0.27	0.02	6.3
3 - 0.5	1.05	0.28	0.03	10.5
– 0.5	1.20	0.44	0.03	11.1
Bulk Sample	0.74	0.27	0.27	100

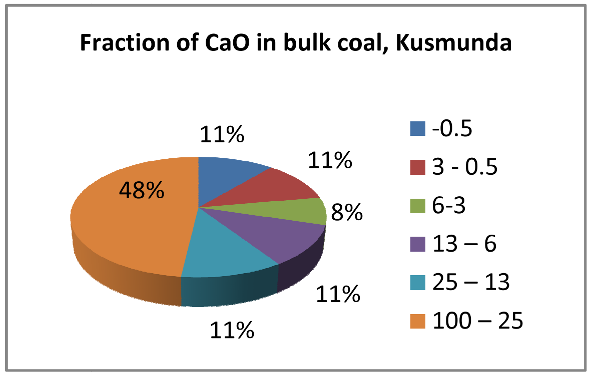

Fig 5: Distribution of CaO in different size fractions

Table 7: Distribution of K_2O in different size fractions Kusmunda seam coal, Korba CF

Size Fraction (in mm)	K_2O% as % of dry ash	K_2O as % of dry coal	Fraction of K_2O in bulk coal (in tonnes)	Fractional % of total K_2O in bulk coal
100 – 25	1.01	0.41	0.23	57.60
25 – 13	1.08	0.38	0.03	8.30
13 – 6	1.09	0.35	0.05	12.30
6 - 3	1.10	0.29	0.02	4.50
3 - 0.5	1.12	0.29	0.03	7.30
– 0.5	1.62	0.59	0.04	10.00
Bulk Sample	1.08	0.40	0.40	100

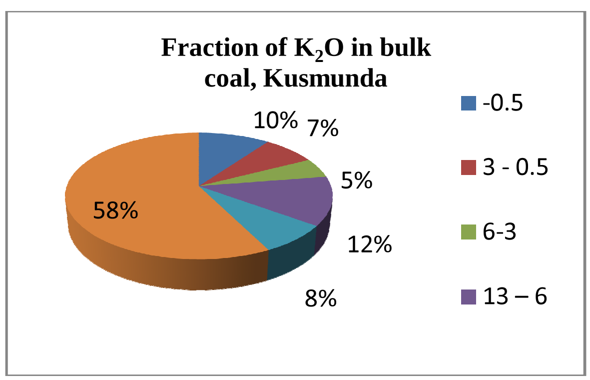

Fig 6: Distribution of K_2O in different size fractions

Table 8: Distribution of TiO_2 in different size fractions Kusmunda seam coal, Korba CF

Size Fraction (in mm)	TiO_2% as % of dry ash	TiO_2 as % of dry coal	Fraction of TiO_2 in bulk coal (in tonnes)	Fractional % of total TiO_2 in bulk coal
100 – 25	1.14	0.45	0.25	62.6
25 – 13	1.11	0.40	0.03	8.8
13 – 6	1.09	0.36	0.05	11.8
6 - 3	1.12	0.30	0.02	5
3 - 0.5	1.03	0.27	0.03	6.8
– 0.5	0.97	0.35	0.02	5
Bulk Sample	1.11	0.40	0.40	100

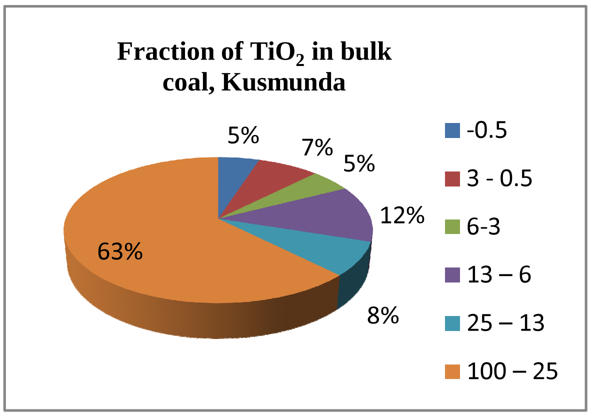

Fig 7: Distribution of TiO2 in different size fractions

Table 9: Composition and properties of Composite Coal samples of Kusmunda coals, Korba coal field.

Size fraction(mm)	Wt %	Dry ash %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	K_2O %	TiO_2 %
+25	54.9	40.4	64.20	30.30	1.55	0.60	0.69	1.01	1.14
–25	45.1	31.3	63.19	29.61	2.76	0.99	0.71	1.20	1.06
+13	63.7	39.7	64.10	30.29	1.58	0.63	0.68	1.03	1.11
–13	36.3	30.3	63.19	29.46	3.00	1.00	0.72	1.27	1.09
+6	76.8	38.4	64.09	30.31	1.66	0.64	0.68	1.05	1.12
–6	23.2	29.2	62.88	28.93	3.54	1.18	0.73	1.33	1.03
+3	83	37.5	64.03	30.30	1.70	0.67	0.69	1.06	1.12
–3	17	30.2	62.91	28.63	3.90	1.17	0.72	1.36	0.97
+0.5	93.1	36.3	64.03	30.21	1.83	0.72	0.69	1.07	1.12
–0.5	6.9	35.9	63.38	27.45	4.44	1.21	0.69	1.61	0.81
Bulk sample	100	36.3	63.87	30.01	1.99	0.75	0.70	1.09	1.11

Table 10: Variation in Ash Constituents in composite samples: SiO_2

Size fraction	+25 mm	–25 mm	+13 mm	–13 mm	+6 mm	–6 mm	+3 mm	–3 mm	+0.5 mm	–0.5 mm
Ash %	40.4	31.3	39.7	30.3	38.4	29.2	37.5	30.2	36.3	35.9
SiO_2%	64.20	63.19	64.10	63.19	64.09	62.89	64.03	62.91	64.03	63.38
Silica as fraction of total coal (in tonnes)	14.24	9.36	16.21	6.95	18.90	4.26	19.93	3.23	21.59	1.57

Table 11: Variation in Ash Constituents in composite samples: Al_2O_3

Size fraction	+25 mm	–25 mm	+13 mm	–13 mm	+6 mm	–6 mm	+3 mm	–3 mm	+0.5 mm	–0.5 mm
Ash%	40.4	31.3	39.7	30.3	38.4	29.2	37.5	30.2	36.3	35.9
Al_2O_3	30.30	29.61	30.29	29.46	30.31	28.93	30.30	28.63	30.21	27.45
Alumina as fraction of total coal (in tonnes)	6.72	4.17	7.66	3.23	8.94	1.95	9.43	1.46	10.21	0.68

Table 12: Variation in Ash Constituents in composite samples: Fe_2O_3

Size fraction	+25 mm	–25 mm	+13 mm	–13 mm	+6 mm	–6 mm	+3 mm	–3 mm	+0.5 mm	–0.5 mm
Ash %	40.4	31.3	39.7	30.3	38.4	29.2	37.5	30.2	36.3	35.9
Fe_2O_3%	1.55	2.76	1.58	3.00	1.66	3.54	1.70	3.90	1.83	4.44
Fe_2O_3 as fraction of total coal (in tonnes)	0.34	0.38	0.40	0.32	0.49	0.23	0.53	0.19	0.62	0.10

Table 13: Variation in Ash Constituents in composite samples: CaO

Size fraction	+25 mm	–25 mm	+13 mm	–13 mm	+6 mm	–6 mm	+3 mm	–3 mm	+0.5 mm	–0.5 mm
Ash %	40.4	31.3	39.7	30.3	38.4	29.2	37.5	30.2	36.3	35.9
CaO %	0.60	0.99	0.63	1.00	0.64	1.18	0.67	1.17	0.72	1.21
CaO as fraction of total coal (in tonnes)	0.13	0.14	0.16	0.11	0.19	0.08	0.21	0.06	0.24	0.03

Table 14: Variation in Ash Constituents in composite samples: K_2O

Size fraction	+25 mm	–25 mm	+13 mm	–13 mm	+6 mm	–6 mm	+3 mm	–3 mm	+0.5 mm	–0.5 mm
Ash %	40.4	31.3	39.7	30.34	38.4	29.17	37.5	30.19	36.3	35.89
K_2O %	1.01	1.20	1.03	1.27	1.05	1.33	1.06	1.36	1.07	1.61
K_2O as fraction of total coal (in tonnes)	0.23	0.17	0.26	0.14	0.31	0.09	0.33	0.07	0.36	0.04

Table 15: Variation in Ash Constituents in composite samples: MgO, Na_2O, SO_3 & P_2O_5

Size fraction	+25 mm	–25 mm	+13 mm	–13 mm	+6 mm	–6 mm	+3 mm	–3 mm	+0.5 mm	–0.5 mm
Ash %	40.4	31.3	39.7	30.34	38.4	29.17	37.5	30.19	36.3	35.89
MgO %	0.68	0.71	0.68	0.72	0.68	0.73	0.69	0.72	0.69	0.69
Na2O	0.08	0.09	0.08	0.09	0.08	0.09	0.09	0.09	0.08	0.1
SO3 %	0.04	0.13	0.04	0.15	0.04	0.21	0.05	0.24	0.06	0.21
P2O5%	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02

Table 16: Properties and Distribution of Ash Constituents in Composite Samples of Kusmunda area, Korba Coal field

Size fraction(mm)	Wt%	Dry ash %	SiO_2%	Al_2O_3%	Fe_2O_3%	CaO%	K_2O%	TiO_2%
+25 incl. (–0.5)	61.8	39.9	64.32	30.01	1.78	0.65	1.09	1.09
–25 excl. (–0.5)	38.2	30.4	63.29	30.05	2.41	0.95	1.12	1.12
+13 incl. (–0.5)	70.6	39.4	63.92	30.00	1.80	0.68	1.08	1.08
–13 excl. (–0.5)	29.4	29.0	63.10	29.91	2.58	0.94	1.17	1.17
+6 incl. (–0.5)	83.7	38.3	63.85	30.00	1.84	0.69	1.09	1.09
–6 excl. (–0.5)	16.3	26.2	63.0	29.74	3.04	1.17	1.17	1.17
Bulk Sample	100	36.3	63.87	30.01	1.99	0.75	1.09	1.11

ACKNOWLEDGEMENT

We are thankful to Mr. B. L. Shah ex-OIC, CIMFR (earlier CFRI), Mr. A. K. Chattopadhyay, OIC and Dr. A. K. Sharma, Principal scientist, CIMFR Bilaspur Unit for their valuable co-operations and suggestions for preparation of this paper.

REFERENCES

1. G. G. Sarkar, “An Introduction to Coal

Preparation Practice", Oxford and IBH publishing Co. Ltd. (1986).
2. BIS 436 (Part I/Section 1 and Part II/Section 2]:- Sampling of coal, 1964, (1976).
3. S. C. Tsai, "Fundamentals of Coal Beneficiation and Utilization" Elsevier Scientific Publishing Company, Amsterdam- Oxford- New York, (1982).
4. BIS 1350 (Part I):-Proximate analysis, (1984).
5. Valkovic Vlado "Trace Elements in Coal Vol - II, CRC Press, (1983).
6. BIS 1355:- Methods of determination of the chemical composition of the ash of coal and coke, (1984).
7. Unpublished Annual reports of Central Fuel research Institute, Bilaspur Unit.
8. Bernard R. Cooper, William A. Ellingson, "The Science and Technology of Coal and Coal Utilization", Plenum Press, New York, (1984).
9. Samir Sarkar, "Fuel and Combustion", Second edition, Orient Longman Limited, Bombay. (1990).
10. Prem S. Tripathy, S.N. Mukherjee, "Perspectives Of bulk use of fly ash", CFRI Golden Jubilee Monograph, Allied Publishers Limited, (1997).